1949-06

Investigation of beach sand stabilization by thermitic means and the design of possible methods of application in the field

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Troy, New York; Rensselaer Polytechnic Institute

http://hdl.handle.net/10945/6438

INVESTIGATION OF BEACH SAND STABILIZATION BY THERMITIC MEANS AND THE DESIGN OF POSSIBLE METHODS OF APPLICATION IN THE FIELD

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INVESTIGATION

OF

BEACH SAND STABILIZATION BY THERMITIC MEANS

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DESIGN OF POSSIBLE METHODS OF APPLICATION IN THE FIELD

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Presented as partial fulfillment of the

requirements for the degree of

Master of Civil Engineering

Rensselaer Polytechnic Institute

Troy, New York

June 1949

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ACKNOWLEDGEMENT

The authors wish to thank Professor E. J. Kilcawley and Professors E. F. Nippes and D. T. Smith for their guidance while this work was being done. It is also desired to express appreciation for the assistance of Mr. William Gamble and Mr. J. R. Louthan in obtaining equipment and supplies to continue the work.

LETTER OF TRANSMITTAL

Rensselaerwyck Housing Development
Troy, New York
June 1949

Faculty of The
Civil Engineering Department
Rensselaer Polytechnic Institute
Troy, New York

Gentlemen:

As partial fulfillment of the requirements for the degree of Master of Civil Engineering, we have the honor of submitting this thesis for your approval. It is hoped that the results of this investigation and the design of the methods for use under combat conditions can be used to advantage by the armed forces if such use becomes necessary.

We should like to express our appreciation for the knowledge and guidance offered us by all members of the Faculty during our two year's of study here at Rensselaer Polytechnic Institute.

Sincerely yours,

Charles B. Coyer
Lieut.(jg)CEC, USN

Larry C. McGuire
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INTRODUCTION

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This investigation is primarily concerned with the stabilization of sands for military purposes. Actual tests were made with amphibious operations in mind, and, for this reason, beach sands were used in the experimentation.

During wartime landing operations, many rubber-tired vehicles must be run ashore from amphibious craft. Sand, in itself, will not support these vehicles unless it happens to contain a certain critical amount of moisture. This condition will normally prevail on little, if any, of the shore area. In order that the vehicles be able to move at all under their own power, the sand must be made to afford some support in addition to that supplied in its natural state. The following investigation presents one method of accomplishing this aim.

Inasmuch as this type of work will normally be applied only to wartime use, certain factors are taken into account:

First, it is recognized that this process may frequently have to be carried out under combat conditions and under enemy fire. For this reason, considerable attention has been given to devising

methods and designing equipment for simplicity and speed.

Second, the roads provided will probably be needed for only a comparatively short period of time. Therefore, the permanence of the finished product need not be a prime consideration.

Third, it is realized that this process is a wartime expedient and will not have extensive application to peacetime use. In its present form, it will not be economically feasible for commercial application because of the prohibitive cost of material and labor.

THEORY

This set of experiments makes use of a high temperature reaction to produce the desired effect. The heat evolved is made use of in two separate and distinct methods, to be explained shortly. The heat is produced by the fusion of thermit.

Thermit is a mixture of iron oxide scale and finely-ground aluminum. When ignited, these react to form iron and aluminum oxide, with large amounts of heat being evolved. The temperature of the reaction is over 5000 degrees Fahrenheit.

METHOD I

In the first method, this heat is used to bring about the formation of a glass-like slab, consisting mainly of silicates. The sand, which consists mainly of silica (quartz) must be mixed with a basic oxide which can furnish an element that will form a silicate of low-melting temperature. Two applicable elements are sodium and calcium. The sodium can be applied as soda ash (sodium carbonate) or as borax, and the calcium as lime (calcium oxide) or as powdered limestone (calcium carbonate). A combination of both elements is used to take advantage of the lower fusion temp-

erature of the sodium silicate, and, according to a source in the United States Navy, the Bureau of Yards and Docks, the greater toughness imparted by the calcium silicate. (The United States Bureau of Mines has no information to corroborate the latter statement.)

The sand is mixed with the proper amount of fluxing agents and a layer of thermit is placed between two layers of the mixture. The heat generated by the fusion of the thermit brings about the formation of a molten slag layer adjacent to the burning thermit.

This slag, which is essentially glass, is formed to a distance of approximately one inch on each side of the melt formed by the thermit itself. Upon cooling, a slab of from 2 to 4 inches total thickness results. This slab has little mechanical strength, as is apparent from its composition. However, when fully supported by the sand below it and covered by a depth of about 3 inches of excess sand mixture to distribute the load to the slab, it can support considerable weight. Thus, a very satisfactory roadway can be produced for the use of rubber-tired vehicles.

METHOD II

In the second method, the heat of the thermit reaction is used to accelerate the setting of water glass (sodium silicate) to form a hard, glassy binder for the sand.

The water glass is applied to the sand above and below the thermit layer. The thermit is ignited and the heat generated quickly drives off the water of hydration from the water glass. This leaves the sodium silicate as a hard material binding the grains of sand together on each side of the slab formed by the fusion of the thermit itself. The grains of sand themselves do not enter into any reaction and are not changed except for some melting in the immediate vicinity of the burning thermit layer.

This method produces a hard slab which, again, has little meahanical strength, but which under the aforementioned conditions of support and overlayment can uphold considerable load.

PREVIOUS INVESTIGATIONS

The only previous work of this kind was done by the U.S. Navy at the Advance Base Proving Ground under the supervision of Mr. G. E. Sanford, connected with the U.S. Naval Construction Battalion Center, Port Hueneme, California. The procedure and results of this investigation were included in the Report on Beach Stabilization Tests of 14 April 1948, by Mr. Sanford.

In this previous test, an area 10 feet wide and 50 feet long was prepared to receive 4 layers of material. The first layer consisted of thermit applied evenly to a depth of about three-quarters of an inch. The second layer was composed of a mixture of sand, soda ash and hydrated lime, approximately 7 inches deep. The third layer was another three-quarter inch layer of thermit, and the fourth layer was another 7 inch layer of mixture of soda ash, lime, and sand.

The plot was ignited from one end, both layers of thermit being lit off simultaneously.

After cooling, the area was tested under varying vehicular loads, the heaviest of which was a $2\frac{1}{2}$-ton truck loaded with 11,000 pounds. Ruts

about 4 inches deep were formed. However, after three or four passes of the truck, the ruts became firm and did not deepen with continued traffic. This operation was repeated several times on different areas of the slab, and each time the excess soda ash, lime, and sand mixture filled in the rut and the area became as firm as the rest of the plot.

The over-all results were satisfactory and the recommendation was made that further investigation of the method be made in an effort to reduce the quantity of material used and to devise a method of application which would reduce the time and labor required.

During the following investigation, the water glass method was devised and tested. As far as the investigators can determine, water glass has never before been used with thermit to stabilize sand.

REPORT

APPARATUS AND MATERIALS USED

1. Thermit packed in nine-pound bags
2. Thermit ignition powder
3. Soda ash in 100-pound bags
4. Hydrated lime in 50-pound bags
5. Shovels
6. Picks
7. Spring balance
8. Safety no-glare glasses
9. Wooden matches

PROCEDURE

For the purpose of the experiments, a pit 3 feet deep and 3 feet square was dug. This pit was filled slightly more than half full of beach sand; beach sand being used to duplicate the type encountered in amphibious landings. On top of this were placed the 3 layers of material used for the various experiments, thermit being the middle layer.

The mixing of the chemicals used in the first method was affected by the use of a one-bag concrete mixer, the chemicals having been carefully weighed out before being shoveled into the mixer. Mixing time varied with the amount of chemicals being mixed; enough time was taken, however, to insure a fairly uniform mixture of the chemicals and the sand.

The layers of chemicals were placed with shovels, care being taken to make the surface of the bottom layer as level as possible before placing the thermit over it.

The thermit was ignited by placing a paper cone down to the level of the thermit layer and putting a small quantity of thermit inside.

About one teaspoon of ignition powder was placed on top of the thermit inside the cone and ignited with the flame of a wooden match head. Paper matches were found unsatisfactory for this purpose because of the lower temperature of ignition of the heads and the paper of the match. A burning thermit puddle must be formed over the thermit layer or combustion will not begin properly.

The load tests were carried out by driving the left front wheel of a $2\frac{1}{2}$-ton truck repeatedly over the test plot, noting the result after each pass of the wheel.

At the conclusion of each test, the used materials were removed from the test pit and the next test started.

METHOD ONE

Two distinct methods of testing were used. In the first, seven tests were run with varying proportions of sand, lime and soda ash under differing conditions.

TEST I

Three layers of materials were used for the test.

1. Mixture of 36 pounds of sand, 7-3/4 pounds soda ash, 1-1/3 pounds lime. Depth about 7 inches.

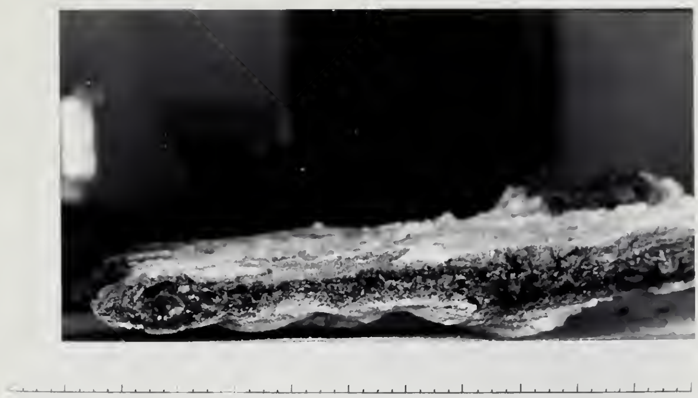
2. Three and one-half pounds of thermit per square foot, making a depth of 1/3 inch.

3. Mixture of sand, soda ash and lime as in layer 1.

The thermit was ignited and burning was about 80% effective. The combustion was vigorous but slow.

The slab was allowed to cool for one hour and then uncovered.

Results were good, resulting in a slab approximately $2\frac{1}{2}$ inches in thickness which seemed to be very hard and tough.



TEST 1 METHOD 1

TEST 2

Three layers of material were used for the test.

1. Mixture of 36 pounds of sand, 18 pounds of soda ash, 6 pounds of lime. Depth about 7 inches.

2. Four pounds of thermit per square foot.

3. Mixture of sand, soda ash, and lime as in layer 1.

The thermit was ignited; combustion was complete and 100% effective.

The slab was allowed to cool for one hour and then uncovered.

Results were excellent. The slab varied from 2 to 4 inches in thickness and was very hard and tough.

TEST 2 METHOD 1

TEST 3

Three layers of material were used for this test.

1. A thoroughly-wetted mixture of sand, soda ash and lime in the same proportions as Test 2.

2. Thermit -- 4 pounds per square foot.

3. Mixture of sand, soda ash and lime in the same proportions as layer 1, wetted thoroughly.

The thermit was ignited and burning was about 40% effective. The combustion was very erratic.

Results were poor, the slab being less than an inch thick and very brittle.

TEST 4

In this test, a concentration of 4 pounds of thermit per square foot was burned between layers of beach sand which were not wetted and to which no chemicals were added.

Combustion was about 90% effective.

Results were poor, the effect of the burning thermit upon the plain sand being negligible. The resulting slab was made up of the thermit metal only and had no appreciable thickness nor strength.

TEST 5

Four layers of material were used for this test.

1. Soda ash laid directly on the sand to a depth of 1/2 inch.

2. Four pounds of thermit per square foot.

3. Soda ash laid over the thermit to a depth of 1/2 inch.

4. About 4 inches of plain sand were then laid over the whole test plot.

The thermit was ignited and burning was 100% effective. The combustion was violent, accompanied by blasts of burning gas issuing from cracks which developed in the surface of the test plot.

The slab was allowed to cool for one hour.

Results were poor. The slab was only about 1 inch in thickness, very brittle and full of blow holes.

TEST 6.

Three layers of material were used for the test.

1. Lime laid directly on the sand to a depth of about 1/3 inch.

2. Four pounds of thermit per square foot.

3. Lime laid directly on the thermit to a depth of about 1/8 inch.

The thermit was ignited and burning was 60% complete. Combustion was slow.

The slab was allowed to cool for one hour and then uncovered.

Results were poor. The slab was only about 1 inch in thickness, made up primarily of thermit slag with very little fusion of sand grains, and was brittle.

TEST 7 - LOAD TEST

The slab obtained from Test 2, having been the best of the six tests, Test 2 was repeated and the slab subjected to a load test as follows:

A $2\frac{1}{2}$-ton truck was used for the testing. The front wheel of the truck was driven onto the test plot. The wheel dropped approximately 4 inches into the pit to make contact with the test surface. A rut approximately 3 inches deep was made, which became firm after repeated passes of the wheel.

The slab was then uncovered and investigation revealed that the slab had cracked, under impact of the dropping wheel, into pieces varying from 3 to 6 inches across. However, the cracking did not seem to affect the load-carrying capacity of the slab greatly, inasmuch as the loads were still carried with little or no vertical displacement of the slab.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

METHOD TWO

Thermit and water glass were the only materials used in the second set of tests.

TEST 1.

One-half quart of water glass per square foot was poured directly on plain sand and allowed to soak in for 10 minutes.

Four pounds of thermit per square foot were spread on this wetted surface.

About 1 inch of dry sand was placed over the thermit and soaked with the same amount of water glass as before. Over this was placed about 4 inches of dry sand.

Upon being ignited, the thermit burned completely and evenly, accompanied by the evolution of a large amount of gas. Results were excellent. The slab formed was of a uniform thickness of approximately 3 inches. It consisted of 2 layers of sand bound together by the sodium silicate, with a small layer of thermit slag in the center. The thermit slag itself contained large blow holes.

TEST 1 METHOD 2

LOWER HALF OF SLAB TEST 1 METHOD 2

TEST 2

For this test, one quart of water glass was mixed with 10 pounds of sand and then spread in a 2-inch layer.

Thermit was placed over this in the amount of 4 pounds per square foot, and about 4 inches of dry sand were spread over the thermit.

Combustion was complete, with not quite as much gas evolved as in Test 1. Results were good. The slab was about 1-1/2 inches thick, but not very uniform. There was less formation of blow holes in the thermit slag.

It is evident from this test that there is no advantage to mixing the water glass with the sand before spreading. In fact, surface application, as in Test 1, seems to give better results.

TEST 3 - LOAD TEST

Test 1 was repeated and the resulting slab tested as follows:

A $2\frac{1}{2}$-ton truck was used. The front wheel of the truck was driven onto the test plot, the wheel dropping about 3 inches in making contact. A rut approximately 3 inches in depth was formed. Repeated runs back and forth over the plot only further compacted the sand over the slab. The rut did not deepen appreciably.

Investigation revealed that the slab had cracked under the impact of the wheel into 3 to 6-inch pieces. However, the load-carrying capacity did not seem to be affected.

There was no noticeable difference between the behavior of this slab and the previously-tested soda ash-lime slab.

TEST 3 METHOD 2

CONCLUSIONS

CONCLUSIONS

On the basis of these investigations, the sodium silicate method appears to have several advantages over the lime and soda ash method. The main difference is in the time of preparation of the site for the ignition of the thermit. The water glass needs only to be poured onto a fairly level surface from containers, while the soda ash and lime have to be put in a mixer, along with large quantities of sand, then removed and spread on the site. The application of water glass obviously is much to be preferred where an enemy is present to hamper operations.

Soda ash and lime present the additional disadvantage of being caustic materials which can cause considerable discomfort to workers whose eyes and noses are not properly protected. In addition, the chemicals must be protected from moisture during transportation to the site.

The cost of materials, as purchased from business establishments, is about equal for the two processes. However, the cost of the soda ash-lime method can be reduced slightly. It is

felt that a 3 inch layer of mixture on each side of the thermit is the maximum necessary, since in none of the tests did the effect of the heat from the thermit reaction extend more than 2 inches from the thermit layer. It does not appear desirable, however, to sacrifice any slab strength by cutting down the percentage of chemicals used in the mixture, since the cost of the chemicals constitutes only about one-sixth of the total cost of the process. It appears that the proportions used in Test 2 are close to the minimum for the formation of a slab of maximum thickness.

On the basis of the strength of the slabs, there appears to be little difference in the two methods. In testing, both of the slabs cracked under the impact of the wheel as it dropped down onto the test plot. However, the vehicles remained supported because the broken slab still presented a solid, if not rigid, surface beneath the excess sand over the slab. Neither slab has great mechanical strength in itself, and both will probably break under heavy loads; yet this cracking is not considered of prime importance since the broken slabs will

still present a solid base for the vehicles to travel upon. No dependable method of measuring actual comparative strength was available, nor deemed necessary.

The one advantage possessed by the soda ash-lime method is that the mixture of these chemicals fills the voids in the sand mass and forms a soil aggregate which will compact to a fairly dense material, particularly in the presence of water. However, this same result can be achieved with easier-to-handle, non-caustic chemicals, such as calcium chloride.

In the application of either method, dry sand is desirable, but not absolutely necessary. The evaporation of the water contained in the wet sand uses up a large amount of the available heat, and usually results in a very thin, porous slab. If such moisture is present, it is recommended that the amount of thermit be increased to 5 or 6 pounds per square foot.

For normal procedure, 4 pounds per square foot of thermit was found to be the minimum practical. Lesser amounts do not burn satisfactorily or completely and do not form a thick enough slab.

DESIGN OF METHOD OF APPLICATION FOR WARTIME USE

METHOD 1

The chemicals and sand cannot be pre-mixed before transportation to the site. Thus, a large mixer must be one of the first pieces of equipment ashore. After mixing, a spreader of the general type used to spread fertilizers on farmland can be used to spread the first layer of the chemical mixture.

On this layer of chemicals, the thermit must be placed. Since placement by hand is a time-consuming and exacting process, it is recommended that the required thickness of thermit be placed beforehand between two sheets of tough paper or cloth and quilted to prevent a shift of the thermit between the sheets. Such a shifting might make the thermit too thick or too thin in places as it is transported. This quilt of thermit is placed on top of the layer of chemical mixture as soon as the latter is placed by the spreader.

One method of preparing the thermit layer beforehand was devised and tested. The thermit was mixed with enough water glass to dampen it

thoroughly and then spread between two sheets of heavy paper, using 4 pounds of thermit per square foot. This was allowed to stand for about one month, during which time the water glass dried enough to bind the thermit into a hard slab. When ignited, the thermit burned completely and very evenly. The uniform thickness of thermit causes a controlled rate of combustion not attained by uneven application. The only drawback to this method is that the thermit would probably have to be formed and left in flat sheets. These might or might not prove to be too difficult to handle, although the investigators see no necessity for using sheets of too great a size.

After the thermit, the final layer of chemical mixture must be applied with shovels, this final operation being the longest and constituting the great disadvantage of the method as compared to the water glass method. The top layer need not be smoothed, however, nor need it be very uniform as long as its thickness exceeds 4 inches.

Truncated cardboard cones, 4 inches tall

with bottom diameters of 1 inch and top diameters of 2 inches filled with thermit and sealed with paper at both ends should be prepared beforehand for use in the ignition of the thermit. To ignite, the cone need only be pressed down through the sand-chemical mixture to the thermit layer, the top paper broken and ignition powder placed on the igniting thermit charge therein. An ordinary wooden match will serve to touch off the ignition powder and start the reaction.

As soon as the plot has cooled (one hour minimum), it may be used for traffic. As long as vehicles are not stopped on the plot, the tires would not be affected by the heat after this period.

METHOD 2

Since the surface of the sand is used directly in the water-glass method, and no chemical layer need be applied, little if any smoothing of the beach is required.

Therefore, a spray tank can be the first piece of equipment off a landing craft. The tank can spray the water glass over the surface of the sand and the placing of the thermit quilt, constructed as in Method 1, can begin immediately.

Over the thermit quilt, plain sand from areas adjacent to the proposed roadway can be shoveled with the help of bulldozers.

The area is then sprayed again from a tank pulled alongside the plot, equipped with nozzles on pipe extensions which reach over the roadway area. These extensions might be incorporated in the same tank which performed the first spraying.

When the spraying has been completed, 2 or 3 inches of dry sand should be applied and ignition of the thermit effected as described in Method 1 using the prefabricated paper cones filled with thermit.

After a similar period of time for cooling, the slab is ready for use in landing operations.

Thesis 10406
C76 Coyer
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